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- **Firat, Hüseyin**  
**FR-75013 - Paris (FR)**
- **Zennou, Véronique**  
**FR-75001 - Paris (FR)**

(71) Applicants:

- **INSTITUT PASTEUR**  
**75724 Paris Cédex 15 (FR)**
- **CENTRE NATIONAL DE  
LA RECHERCHE SCIENTIFIQUE**  
**75016 Paris Cédex (FR)**

(74) Representative: **Desaix, Anne et al**  
**Ernest Gutmann - Yves Plasseraud S.A.**  
**3, rue Chauveau-Lagarde**  
**75008 Paris (FR)**

(72) Inventors:

- **Charneau, Pierre**  
**FR-75005 - Paris (FR)**

Remarks:

The applicant has subsequently filed a sequence listing and declared, that it includes no new matter.

**(54) Lentiviral vectors for the preparation of immunotherapeutical compositions**

(57) The invention relates to an immunogenic composition comprising a recombinant vector characterized in that it comprises a polynucleotide comprising the cis-acting central initiation region (cPPT) and the cis-acting termination region (CTS), these regions being of retroviral or retroviral-like origin, said vector comprising in addition a defined nucleotide sequence (transgene or

sequence of interest) and regulatory signals of retrotranscription, expression and encapsidation of retroviral or retroviral-like origin, wherein the composition is capable of inducing or of stimulating a cell-mediated response for instance a CTL (Cytotoxic T Lymphocytes) response or a CD4 response, against one or several epitopes encoded by the transgene sequence present in the vector.

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## Description

[0001] The present invention relates to the use of retroviral vectors, and especially lentiviral vectors for the preparation of compositions which are capable of inducing or contributing to the occurrence or improvement of an immunological reaction *in vitro*, and in a preferred embodiment *in vivo*, against epitopes which are encoded by nucleotide sequences present in the vectors.

[0002] The inventors have shown that vectors prepared in accordance with the present invention enable to obtain a cell-mediated immune response, especially a Cytotoxic T Lymphocytes (CTL) reaction against epitopes.

[0003] They have furthermore obtained data showing that this cell-mediated immune response can be a specific response, obtained against one or several epitopes encoded by the nucleotide sequence contained in the vectors.

[0004] Therefore, the invention provides means which could be used in treatment protocols against tumors and cancer and especially could be used in protocols for immunotherapy or vaccination therapy against tumors.

[0005] The invention also discloses means that could be used for the treatment or prophylaxis of infectious diseases, especially diseases associated with virus infection and for instance, with retrovirus infection.

[0006] The inventors have further obtained results showing that the cell-mediated immune response and especially the CTL response associated with the treatment by the compositions of the invention can be specific for the antigen of the tumor or of the virus or virus infected cells, and can also be restricted to specific molecules of the MHC (Major Histocompatibility Complex).

[0007] Particularly the invention relates to the use of the vectors in immunogenic compositions, in order to obtain a cell-mediated immune response restricted to Class I molecules of the MHC complex and for instance restricted to HLA-A2 or B7 molecules.

[0008] Accordingly, the invention relates to an immunogenic composition comprising a recombinant vector which comprises a polynucleotide encompassing the cis-acting central initiation region (cPPT) and the cis-acting termination region (CTS). During reverse transcription, cPPT and CTS sequences induce the formation of a three stranded DNA structure here referred as DNA triplex. The DNA triplex stimulates the nuclear import of vector DNA genomes, these regions being of retroviral or retroviral-like origin, said vector comprising in addition a defined nucleotide sequence (transgene or sequence of interest) and regulatory signals of retrotranscription, expression and encapsidation of retroviral or retroviral-like origin, wherein the composition is capable of inducing or of stimulating a CTL (Cytotoxic T lymphocytes) or a CD4 response against one or several epitopes encoded by the transgene sequence present in the vector.

[0009] In a preferred embodiment of the invention, the cell-mediated immune response and especially the CTL response or the CD4 response against one or several epitopes is a memory CTL or a CD4 response.

[0010] It is emphasized that the presence, in the vector, of the cPPT and CTS regions enables the triplex DNA structure to be formed thereby influencing and especially improving the nuclear import of the genome of the vector in cells recombined with said vector.

[0011] This capacity of the immunogenic composition according to the invention to induce, improve or in general be associated with the occurrence of a memory CTL response, enables to propose the use of the immunogenic composition in protocols of anti-tumor therapy or antiviral or antipathogenic therapy, including when the immune response has to be induced on long lasting period of time or at least inducible when a response is sought at a period of time which can be long term induction of the response, after the administration of the immunogenic composition. In other words the immunogenic composition can be used for the preparation of therapeutic composition for the treatment of tumor diseases or infectious diseases, for instance by bacteria or viruses, by inducing or stimulating or participating to the occurrence of a cell-mediated immune response, especially a CTL response or a memory response.

[0012] It is emphasized that the immunogenic composition of the invention, as a consequence of the presence of the triplex structure in the sequence of the vector, resulting from the presence of the cPPT and CTS regions in the vector and in the vector particles, enables the stimulation of the nuclear import of the genome of the vector, in target cells. The induced epitopes in the vector can be self or non-self.

[0013] The present invention covers also the use of a nucleotidic sequence comprising the cPPT and CTS sequences of retroviral or synthetic origin for increasing the entry of nucleotidic or peptidic sequences in the nucleus of the target cells or recipient cells.

[0014] As an example, it is understood that the said triplex sequence comprises foreign sequences or self sequences with respect to the recipient cells.

[0015] Thus, the invention discloses a composition that could be used in therapeutic protocols that present analogies with vaccination protocols, for the treatment of tumors and especially as anti-cancer or anti-infectious diseases treatment.

[0016] It is of interest to note that in accordance with the present invention, this transgene or sequence of interest can be a sequence encoding one or several epitopes of one or several tumor cells, for instance epitopes that have been identified in potential target antigens for the induction of a cell-mediated immune response against the tumor.

[0017] Several epitopes forming a polypeptide, can be encoded by the transgene of the invention. In a particular embodiment, they can be derived from target antigens identified in the tumor, and can be chosen in such a way that when their coding sequence is combined to form the transgene, a cell-mediated immune response is obtained against all the epitopes or against most of them. The cell-mediated immune response can be assayed *in vitro* or in a preferred embodiment *in vivo*. Protocols enabling to carry out such assays are described in the Examples.

[0018] Target antigens have been identified in several types of tumors and in particular in melanomas or in carcinomas, including renal carcinomas, Bladder carcinomas, colon carcinomas, lung carcinomas, breast cancer, leukemia and lymphoma...

[0019] According to another aspect of the invention, the immunogenic composition can be used in order to obtain a cell-mediated immune response, in infectious diseases, including viral-associated infection, or infection linked to any kind of pathogen, including Mycobacteria, for instance, *M tuberculosis*.

[0020] In this case specific antigens capable of eliciting a cell-mediated immune response, can be identified and their coding sequences inserted in the vector used in the immunogenic composition. As example the *des* gene of *M tuberculosis* can be used

[0021] It is also added that in accordance with the present invention, the vectors which are used in the immunogenic compositions may express epitopes or present on proteins (including glycoproteins or other protein-derived compounds) identified as target antigens on tumor cells or on virus-infected cells.

[0022] In addition, it is noted that epitopes, polypeptides or proteins used to provide epitopes, can be modified, for instance by mutation, deletion or insertion and for example can be modified to improve their stability.

[0023] The invention also relates to an immunogenic composition comprising recombinant retroviral particles comprising :

1) a recombinant nucleotide sequence containing a defined nucleotide sequence (transgene), placed under the control of regulatory signals of transcription and expression, regulatory signals of retrotranscription, expression and encapsidation and,

2) a polynucleotide encompassing the cis-acting central initiation region (cPPT) and a cis-acting termination region (CTS), these regions being of retroviral or retroviral-like origin or from a transposon and being inserted in a functional orientation and location with retrotranscription regulatory signals of retroviral or retroviral-like origin or with transposons regulatory signals,

wherein the immunogenic composition is capable of inducing or of stimulating a CTL (Cytotoxic T Lymphocytes) response against one or several epitopes encoded by the transgene sequence present in the vector.

[0024] The DNA fragment encompassing the cPPT and CTS cis-active sequences is able to adopt a three stranded DNA structure the "DNA triplex" after reverse transcription and to stimulate the nuclear entry of the vector DNA.

[0025] According to a particular embodiment, the immunogenic composition which is capable of inducing or of stimulating a CTL (Cytotoxic T Lymphocytes) response against one or several epitopes encoded by the transgene sequence present in the vector, comprise recombinant retroviral vector particles comprising:

a) a *gag* polypeptide corresponding to nucleoproteins of a lentivirus or to functional derived polypeptides (GAG polypeptides),

b) a *pol* polypeptide constituted by the RT, PRO, IN proteins of a lentivirus or a functional derived polypeptide (POL polypeptide),

c) an envelope polypeptide or functional derived polypeptides (ENV polypeptides),

d) a recombinant nucleotide sequence comprising a defined nucleotide sequence (transgene or a sequence of interest), coding for one or several epitopes, placed under the control of regulatory signals of transcription and expression, a sequence containing regulatory signals of retrotranscription, expression and encapsidation of retroviral or retroviral-like origin and a polynucleotide containing a cis-acting central initiation region (cPPT) and a cis-acting termination region (CTS), these regions being of retroviral or retroviral-like origin and being inserted in a functional orientation with the above-mentioned regulatory signals of retroviral or retroviral-like origin. According to another embodiment, the immunogenic composition which is

capable to induce or to stimulate a CTL (Cytotoxic T Lymphocytes) response against one or several epitopes encoded by the transgene sequence present in the vector comprises recombinant retroviral-like particles which comprise:

a) a polynucleotide containing a cis-acting central initiation region (cPPT) and a cis-acting termination region (CTS), these regions being derived from a retrotransposon and inserted in a functional orientation with retrotransposon regulatory signals,

b) a polypeptide corresponding to the nucleoproteins of a retrotransposon or to functional derived polypeptides

(GAG polypeptides)

c) a pol polypeptide corresponding to RT, PRO, IN proteins of a retrotransposon or a functional derived polypeptide (POL polypeptide).

d) a viral envelope polypeptide.

e) a recombinant nucleotide sequence comprising a defined nucleotide sequence (transgene or sequence of interest), placed under the control of regulatory signals of transcription and expression, retrotransposon regulatory signals of retrotranscription, expression and encapsidation. The recombinant retroviral vector particles which are present in the

immunogenic composition replying to one or the other above-definition are in a preferred embodiment capable of inducing, improving or being associated to the occurrence of a memory cell-mediated immune response and especially a memory CTL response.

**[0026]** In accordance with the above disclosed definitions of the immunogenic composition containing the vectors or vector particles can be prepared in accordance with several possible embodiments.

**[0027]** In a preferred embodiment of the invention, the immunogenic composition is prepared in such a way that the sequences of retroviral origin are derived from a lentivirus genome.

**[0028]** According to another embodiment, these sequences are of retroviral-like origin and are derived from retrotransposon.

**[0029]** In another embodiment of the invention, or in addition to the above-defined features, the transgene or sequence of interest which is contained in the recombinant vector is contained in an expression cassette including regulatory signals of transcription and expression.

**[0030]** Alternatively, the regulatory signals of retrotranscription, expression and encapsidation of the vector are of lentiviral origin and the polynucleotide comprising the cPPT and CTS regions is of lentiviral origin.

**[0031]** According to another embodiment, the regulatory signals of retrotranscription, expression and encapsidation and the polynucleotide comprising the cPPT and CTS regions in the vector, are derived from a HIV-type retrovirus, in particular HIV-1 or HIV-2.

**[0032]** Other viruses and especially lentiviruses can be used to design the regulatory signals of retrotranscription expression and encapsidation, and also to derive the polynucleotide comprising the cPPT and CTS regions. Especially, the lentiviruses CAEV, EIAV, VISNA, HIV, SIV or FIV can be used therefore.

**[0033]** For the obtention of the recombinant retroviral particles of the immunogenic composition of the invention, sequences encoding polypeptides or proteins necessary for the transcomplementation of the vectors are for instance GAG, POL and ENV proteins derived from lentiviruses, and especially from HIV, including HIV-1 and HIV-2 retroviruses.

**[0034]** Alternatively, the GAG and POL sequences may be derived from a different virus than the ENV sequence. For instance, GAG and POL sequences can be derived from the HIV retrovirus and the ENV sequence can be derived from another virus or retrovirus, and can be either amphotropic or ecotropic ENV sequences.

**[0035]** In another embodiment, the ENV sequence is derived from the vesicular stomatitis virus (VSV).

**[0036]** According to a particular embodiment of the invention, the immunogenic composition which is capable to induce or to stimulate a CTL (Cytotoxic T Lymphocytes) response against one or several epitopes encoded by the transgene sequence present in the vector comprises recombinant retroviral-like particles which comprise:

a) a polynucleotide containing a cis-acting central initiation region (cPPT) and a cis-acting termination region (CTS), these regions being derived from a retrotransposon and inserted in a functional orientation with retrotransposon regulatory signals,

b) a polypeptide corresponding to the nucleoproteins of a retrotransposon or to functional derived polypeptides (GAG polypeptides)

c) a pol polypeptide corresponding to RT, PRO, IN proteins of a retrotransposon or a functional derived polypeptide (POL polypeptide),

d) a viral envelope polypeptide,

e) a recombinant nucleotide sequence comprising a defined nucleotide sequence (transgene or sequence of interest), placed under the control of regulatory signals of transcription and expression, retrotransposon regulatory signals of retrotranscription, expression and encapsidation. The immunogenic composition of the invention which comprises the

recombinant retroviral-like particules are in a preferred embodiment capable of generating a memory cell-mediated response, especially a memory CTL response, in accordance with the above-disclosed features.

**[0037]** The invention also relates to vector constructs which have been deposited with the CNCM (Collection Nationale de Culture de Microorganismes at Institut Pasteur in Paris, France) on October 11, 1999.

**[0038]** A first vector is pTRIP.TEL/AML-IRES-GFP, deposited under number I- 2326 on October 11, 1999 and a

second vector is designated pTRIP-ILKE -IRES-GFP, and has been deposited under number I-2327 on October 11, 1999.

[0039] A third vector, pTRIP.DES-IRES-GFP has been deposited with the CNM under number I-2331 on October 11, 1999.

[0040] The sequences encoding the antigens that are present in the above constructs can be replaced by any other antigen or epitope of interest, including the above cited complete DES gene of *M tuberculosis*.

[0041] According to another aspect of the invention, the vectors, vector particles and immunogenic compositions comprising the same, are designed in such a way that the cPPT and CTS regions are localized centrally within the sequence of the vector.

[0042] By « localized centrally », it is meant that the cPPT and CTS regions are in the center of the sequence of the vector, or approximately in the center of this sequence. Especially, the cPPT and CTS regions can be within the central one third of the retrotranscribed linear vector DNA.

[0043] The central localization of the triplex sequence formed during viral retrotranscription as a consequence of the presence of the cPPT and CTS sequences enable an improvement of the level of transduction of cells contacted with the vector or vector particles.

[0044] Alternatively, according to a variant of the vector, the transcription unit of the vector, including the transgene can be inserted within the U3 region of the LTR region. Accordingly, after retrotranscription, the transgene is duplicated and therefore appears on each side of the triplex sequence, therefore enabling the triplex sequence to be localized at the central position in the vector, whatever the size of the transgene.

[0045] The invention also relates to cells which have been put in contact with the immunogenic composition according to the invention and especially relates to recombinant cells transduced by the vector or vector particles of the immunogenic composition.

[0046] These cells are advantageously antigen presenting cells. As example these cells can be chosen among lung cells, brain cells, epithelial cells, astrocytes, microglia, oligodendrocytes, neurons, muscle, hepatic, dendritic, neuronal cells, cells strains of the bone marrow, macrophages, fibroblasts, hematopoietic cells.

[0047] The immunogenic composition of the invention can thus be used in treatment protocols or for the preparation of treatment compositions for the therapeutic treatment of tumors and especially of cancer, either to generate a primary cell-mediated immune response, especially a CTL response which is advantageously a memory CTL response. Alternatively, it can be used as an adjuvant treatment with other known anticancer treatment.

[0048] For instance, the immunogenic composition of the invention can be used in association with chemotherapy or immunochemotherapy or other approaches to anticancer treatment.

[0049] By the expression « anticancer treatment », it is intended in accordance with the present invention, the inhibition of growth of the tumor or potential growth of the tumor or the inhibition of spread of the malignant cells, including the possibility of controlling formation of metastasis, or both.

[0050] Therefore, according to the invention, the expression « anticancer treatment » relates to protocols that are used to control the malignant growth and spread of tumors, do anticipate recurrence of the disease, especially in view of the fact that the immunogenic composition is capable of inducing or improving, and in general participating to, a memory cell-mediated response.

[0051] Tumors that may be treated with the compositions of the invention, are for instance melanomas or carcinomas including (lung, bladder, renal, colon) and Lymphoproliferation.

[0052] The tumors that may be treated are also all the tumors expressing tumor specific antigens including self protein mutated and/or self protein overexpressed.

[0053] Every possible acceptable ways of administration of the immunogenic composition of the invention are of interest including administration protocols comprising *ex vivo* steps, for instance *ex vivo* transduction of target cells followed by administration of the treated cells to the patient to be treated.

[0054] Alternatively, the immunogenic composition according to the invention can be directly administered to the patient through usual routes of administration, including systemic (IV), locally, or cutaneously, intradermic, for instance intratumoral, administration routes.

[0055] In a particular embodiment, the immunogenic composition according to the invention can be directly administered to the patient, in such a way that it will induce, improve or participate *in vivo* to the occurrence of a cell-mediated immune response, especially a CTL-mediated immune response.

[0056] In another embodiment, the immunogenic compositions are used so that they can enable the occurrence of a long-term memory cell mediated response.

[0057] It is emphasized that the immunogenic composition of the invention has a particular interest due to the property of the cPPT and CTS sequences which are present in the vector and vector particles, to induce or to stimulate the nuclear import of the vector genome in the target cells.

[0058] A particular advantage of the immunogenic compositions of the invention is that they can be used to elicit or stimulate a cell-mediated immune response against multiple epitopes encoded by the nucleotides sequence of interest

or transgene present in the vector or vector particles, and they can also be used to elicit or stimulate a cell-mediated immune response against the product of the entire sequence of a gene, for instance a gene of a pathogenic agent or fragments of said gene capable to encode at least 8 to 15 amino acids preferably 9 to 12 amino acids. The invention covers also a nucleotidic sequence comprising nucleotidic sequence encoding a multiple repeat (at least 2 identical sequences) of said amino acid sequence inducing a cellular response and/or an amino acid sequence containing at least 2 different sequences corresponding to 2 epitopes of different pathogens or tumoral antigens.

[0059] Other characteristics or advantages of the invention are disclosed in the following examples and drawings.

#### Legend of the figures

[0060] Figure 1: HIV1-derived triplex DNA positive recombinant vector encoding a melanoma polyepitope.

[0061] Figure 2: CTL responses of HHD mice after immunization with the TRIP-mel-IRES-GFP vector.

[0062] Figure 3: GFP expression in human cells 5 days after their transduction by the central DNA triplex positive or negative HIV1-derived vectors.

[0063] Figure 4: *In vitro* CTL responses using human dendritic cells.

[0064] Figure 5: Restriction Card of pHR.MEL-IRES-GFP vector Melanome specific CTLs mono or polyepitope sequences

#### Construction of HR.MEL-IRES-GFP

[0065] To construct the HL.MEL-IRES-GFP plasmid, the NdeI/XhoI fragment of TRIP.MEL-IRES-GFP deposited at the CNCM under n° I-2185 on April 20, 1999 containing part of the CMV promotor, the polyepitope MEL and the IRES-GFP instead of NdeI/XhoI fragment of HR GFP containing a part of the CMV promotor and the GFP.

[0066] Figure 6: Restriction Card of pTRIP.ILKE-IRES-GFP vector

HIV specific CTLs mono or polyepitope sequences, the epitope of which 19V.(ILKE) : (RT 476-484)

Construction of TRIP.ILKE-IRES-GFP (deposited at the CNCM, Paris, France on October 6, 1999 under n° ...

TRIP.ILKE-IRES-GFP was constructed by inserting the PCR product of ILKE into TRIP ΔE IRES-GFP, between the CMV promotor and the IRES. The region surrounding the CTL epitope beginning by ILKE was amplified by PCR on the matrix pLAI with the primers :

5 ILKE : 5'TCAGATCTGCCACCATGGCACTAACAGAAGTAATACCAC 3'

3 RIILKE : 5' CGGAATTCTTATTGGCCTTGCCCCTGCTTC 3'.

[0067] A Kozak sequence was inserted into the upstream primer and a stop codon was inserted into the downstream primer.

[0068] After digestion of with BglII/EcoRI the PCR product was inserted into TRIP ΔE IRES-GFP into the BamHI/EcoRI sites.

[0069] The vector expresses a bi-cistronic messenger coding for GFP and a region of the RT gene of VIH, corresponding to a cluster of epitopes, comprising especially the 19V epitope (RT 476-484) restricted to HLA.A2.1 (Walker B.D., 1989 PNAS 86 p. 9514-9518).

[0070] Figure 7: Restriction Map of pTRIP.TEUALM-IRES-GFP vector

Translocation TEL/AML Sequence

TRIP.TEL/AML-IRES-GFP was constructed by inserting the PCR product of TEL/AML into TRIP ΔE IRES-GFP, between the CMV promotor and the IRES. The region surrounding the translocation between TEL and AML was amplified by PCR with the primers :

5 Bgl TA : 5'GAAGATCTGCCACCATGAAGCCCATCAACCTCTCTCAT 3'

3 RITA : 5' CGGAATTCTTACCCAGCGCAACGCCTC 3'

[0071] A Kozak sequence was inserted into the upstream primer and a stop codon was inserted into the downstream primer.

[0072] After digestion of with Bgl II/EcoRI the PCR product was inserted into TRIP ΔE IRES-GFP into the BamHI/

EcoRI sites.

[0073] Figure 8: Transduction capacity of HIV-derived DNA triplex positive vector encoding 19V epitopic peptide (derived from HIV 1 pol) and GFP of murine dendritic cells that were produced using bone marrow cells from HHD transgenic mice. About 80% of murine dendritic cells are transduced by the HIV derived triplex positive recombinant vector as documented by FACS analyses of intra cellular GFP expression.

[0074] Figure 9: Evaluation of CTL responses in HHD mice after immunization with the TRIP-des-IRES-GFP vector encoding the DES gene of *Mycobacterium tuberculosis*.

[0075] Figure 10: Restriction map of pTRIP.DES-IRES-GFP deposited with the CNCM on October 11, 1999.

## EXAMPLES

[0076] Lentiviral vectors have the capacity to transduce cells, including non dividing cells, and are increasingly proposed for gene therapy. Recently, we showed that lentiviral vectors containing the polypurine tract cis-acting sequence (central DNA triplex) exhibit more efficient transduction of human and murine cells than those deleted for the central DNA triplex (Chameau P. et al, J. Mol. Biol. 1994, 241, 651-662). Lentiviral vectors containing or not central DNA triplex and encoding the same HLA-A2.1 restricted melanoma CTL polyepitope have now been tested for their capacity to induce CTL responses. The direct *in vivo* administration of the lentiviral vector containing central DNA induced strong CTL responses against all epitopic peptides encoded by the polyepitopic sequences in HHD «HLA-A2.1 pure» mice. A clear advantage was shown for the lentiviral vector containing the DNA triplex. Furthermore, we showed that the lentiviral vector containing the DNA triplex transduce the human dendritic cells up to 7-fold more efficiently than the vector not containing the triplex. These *ex vivo* transduced dendritic cells elicited efficient specific primary CTL responses against most of the melanoma epitopic peptides. Since the safety concern of modified lentiviral vector has been mostly resolved, we propose the use of that vector not only for *in vivo* human gene therapy, but also for immunotherapy of cancer patients.

## Introduction

[0077] The Lentiviridae subclass of retrovirus can infect most cell types including non-dividing cells. This property makes lentivirus attractive for gene therapy. Several replication-defective recombinant lentiviral vectors have already been constructed by different groups (Naldini PNAS 93, 11382-8, Science, 1996). These reengineered and detoxified lentiviral vectors are proposed as the most efficient and safe gene therapy vectors (Zufferey R. & Kim V.N. J Virol, 72, 9873-80, 1998). We developed a human lentiviral (HIV)-based vector, pseudotyped with vesicular stomatitis virus G glycoprotein (VSVG) (Burns J.C., 1993 PNAS 90, 8033-7). This vector was deleted for most of the non essential viral proteins but contains a polypurine tract cis-acting sequence (cPPT, central DNA triplex). The central DNA triplex considerably enhances the nuclear import of retrotranscribed HIV-DNA molecules. Moreover, it was observed that the lentiviral vector containing the central DNA triplex displays more efficient transduction of murine and human cells *in vitro* than the vector not containing the triplex.

[0078] The HHD «HLA-A2.1 pure» transgenic mouse (Pascolo et al., J. Exp. Med., 1997, 185 : 2043-2051) allow for an experimentally controlled evaluation of the immunogenic potential of epitopic peptides and of various immunisation strategies. Using these HHD mice, the capacity of a melanoma polyepitope encoded by different recombinant vectors to induce simultaneous CTL responses within a single animal has been reported. The capacity of lentiviral vectors containing or not central DNA triplex and encoding the same melanoma polyepitope for *in vivo* CTL induction in HHD transgenic mice has first been studied. Furthermore, it was also investigated whether human dendritic cells (hDC) transduced by the same recombinant lentiviral vectors induce primary CTL responses against the melanoma polyepitopic motive *ex vivo*. The present results demonstrate that the DNA triplex enhances significantly the capacity of lentiviral vector to induce specific CTL responses *in vivo* by direct administration of the recombinant vectors or *ex vivo* using transduced dendritic cells.

## Results

### Example I: Melanoma polyepitopic immunisation

[0079] After establishing that injection of recombinant-DNA encoding a melanomaderived polyepitopic motif can elicit simultaneously CTL responses against several melanoma epitopes in HHD mice, the immunogenic capacity of a lentivirus vector encoding the same melanoma polyepitopic motive (Fig. 1 and Table 1) was tested. A TRIP-mel-IRES-GFP vector (CNCM 1-2185 deposited on April 20, 1999) was administered at 1.25µg/p24 per mouse either intravenously, intra peritoneally, or subcutaneously. At least 3 mice per group were used.

[0080] Multiple specific CTL responses were simultaneously induced against most of the ten melanoma epitopes.

Similar CTL responses were observed regardless of the route of administration against both peptide loaded (Table 2) and TRIP-mel-IRES-GFP transduced, HHD-transfected HeLa cells (data not shown). However, intraperitoneal injection induced slightly better CTL responses. Strong responses were elicited against NA17-A.138 and gp100.154 epitopic peptides. Significant responses were also observed against gp100.457, MART.1.27, Mage-3, and Tyrosinase.368-D. CTL responses were weak against gp100.209, gp100.280, MART-1.32, and Tyrosinase.1. The epitopes which elicit weak CTL responses following TRIP-mel-IRES-GFP vector immunisation all fall into the non CTL-inducer groups when administered using other non lentiviral vectors.

#### Minimal lentiviral vector dose required for *in vivo* detectable CTL induction

[0081] The minimal lentiviral vector dose eliciting a significant CTL response was determined in HHD mice using intraperitoneal injections of TRIP-mel-IRES-GFP vector at six different doses using 4 mice per dose. Two experiments were performed in which effector cells of two mice were mixed to have similar E/T ratios just before the  $^{51}\text{Cr}$  test. In most experiments CTL responses were tested against all melanoma epitopic peptides. Because the results were highly similar and very homogeneous, only CTL responses against NA17/A epitopic peptide were taken into account to compare «dose-effect» relationship for the sake of clarity and simplicity. The best CTL responses were obtained using doses between 500ng and 2500ng/p24 per mouse (Table 2). Although detectable CTL responses were obtained against some of the melanoma epitopes, high lentiviral doses did not induce better CTL responses than low doses. Even though, some specific CTL responses against some of the melanoma epitopic peptides were evidenced, doses below 500ng/p24 per mouse were not sufficient to induce efficient CTL responses. It is noteworthy that at the dose of 1250ng/p24 per mice, some mouse generated CTL responses against ten out of ten epitopes included in the polyepitopic motif (Fig. 3).

#### Long term memory CTL induction

[0082] Eight mice were injected with the TRIP-mel-IRES-GFP vector. The mice were sacrificed either 12 days or 5 months after immunization. After 5 days *in vitro* stimulation with the melanoma epitopic peptides and two additional day with 10% TCGF, effector cells of four mice were mixed and tested against peptide loaded HHD-transfected RMAS cells. Specific CTL responses were evidenced for all melanoma epitopic peptides but for gp100.209 and Mart1.32 in mice immunized 12 days before. Five months after injection of the TRIP-mel-IRES-GFP, all of the primary CTL inducer epitopes still induced strong CTL responses (Fig. 2). The level of CTL responses 12 days or 5 months after immunization of mice was surprisingly comparable. This suggests that *in vivo* transduced cells by the lentiviral vector are not destroyed by the immune system and continue to produce the encoding melanoma poliepitope.

#### Role of the central DNA triplex for *in vivo* immunisation

[0083] HHD mice were immunised individually at the same time with the TRIP-mel-IRES-GFP and HR-mel-IRES-GFP vectors administered intraperitoneally at doses of 800ng, 200ng, 50ng, 12ng, and 3ng/p24 per mouse. At least four mice were tested for each dose in two separate experiments. After *in vitro* stimulation by synthetic peptides, the cytolytic capacity of spleen cells was tested using peptide pulsed RMAS-HHD target cells. Because the results were highly homogeneous, only CTL responses against NA17/A, Mart-1.27, gp100.154, and Tyrosinase.368-D epitopic peptide were tested for the sake of clarity and simplicity.

[0084] The results are illustrated in Table 3. In general, the mice immunised with the TRIP-LV vector at doses of 800ng, 200ng, and 50ng/p24 per mouse, elicited better CTL responses than the mice immunised with the HR-LV vector. There was no detectable CTL response at the dose below 12ng/p24 per mouse regardless of the vectors used (data not shown). This confirms the enhanced transduction capacity of lentiviral vectors containing the central DNA complex in comparison with those lacking this complex.

#### Dendritic cells transduction by the lentiviral vectors

[0085] It was initially observed that tumor cells such as MT4 and HeLa cells can be transduced up to 30-fold more efficiently by the lentiviral vector containing the central DNA triplex than by the vector lacking the central DNA triplex. The transduction capacity of these two lentiviral vectors at different concentrations was then tested on DC from healthy donors or from HHD mice. The percentage of DC expressing GFP and their mean intensity of fluorescence were measured by FACS and considered as the transduction level of DC by the two lentiviral vectors.

[0086] The TRIP-GFP vector transduced the cells more efficiently than the HR-GFP vector at all vector concentrations. The GFP expression of murine and human DC transduced by the TRIP-GFP vector was respectively up 3- and 7-fold higher than the expression of those transduced by the HR-GFP vector (Fig. 4).

## Primary CTL induction using human dendritic cells transduced by TRIP mel IRES-GFP vector

[0087] Mononuclear cells (MNC) obtained from healthy HLA-A2.1 donors were stimulated *in vitro* once a week using the DC from the same donor transduced by TRIP mel- IRES-GFP. The presence of GFP expression in the dendritic cells was analysed by FACS to verify efficient transduction. After three weeks, the cytotoxic capacity of the MNC was tested in a  $^{51}\text{Cr}$  assay using peptide pulsed T2 cells as targets in FCS free culture condition.

[0088] The hDC transduced with the TRIP-mel-IRES-GFP vector induced significant CTL responses against all melanoma epitopic peptides but Mart1.31, whereas non transduced hDC induced only habitual background responses (Fig. 5).

## Discussion

[0089] Recent reports show that replication defective lentivirus derived vectors can transduce a variety of nondividing cells (Naldini, 1996, Kafri, 1997). Lentivirus can enter through the intact nuclear membrane of nondividing cells (Case, 1999). We have now evidenced that this procedure is largely orchestrated by a polypurine tract cis-acting sequence, denominated the central DNA triplex. Introduction of this sequence into the lentiviral-derived vectors allowed for up to 30-fold higher *in vivo* and *ex vivo* stable transduction of several cell types including neurons, hepatocytes, and hematopoietic stem/progenitor cells.

[0090] Recently, progress has been accomplished to address the safety concern of lentivirus-derived vectors and their use in gene therapy (Narry Kim V et al 1988, Zufferey, 1999). However, lentiviral vectors have never been studied for immunotherapy applications for which classical murine retroviral vector and non retroviral vectors were successfully used (Condon, 1996, Song 1997, Specht, 1997). To develop a potent vaccine strategy, the immunogenic capacity of a lentiviral vector containing the central DNA triplex and encoding a melanoma polyepitope has been tested. Direct injection of this vector was first studied to assay whether it can elicit *in vivo* specific CTL responses against the melanoma epitopes. Previously several immunisation strategies in HHD HLA-A2.1 « pure » transgenic mice were compared. Using recombinant pCMV-B10 (HBs) DNA or recombinant vaccines encoding the same melanoma polyepitope, it was possible to simultaneously induce, in a single mouse, CTL responses against four to six different peptides included in the melanoma polyepitope. For the TRIP mel IRES-GFP vector encoding the same melanoma polyepitope, we obtained significantly better results than with other vectors encoding the same poliepitopic motive in terms of specific lysis but also in terms of number of peptides eliciting CTL responses. Particularly, intraperitoneal and subcutaneous injection of vector induced in some mice CTL responses against all epitopes encoded by the TRIP mel IRES-GFP vector.

[0091] Several groups reported that dendritic cells which are transduced or peptide loaded can be used as a potent immunisation approach against a variety of cancer cells (Mayardomo, JI, 1995, Song W, 1997, Specht, JM, 1997). For the purpose of this invention, it was therefore studied whether murine and human dendritic cells can be transduced efficiently and induce primary CTL responses *in vitro*. The present results clearly demonstrate that these cells can easily be transduced. Furthermore, these transduced cells presented all epitopes encoded by the recombinant lentiviral vector. Interestingly, human dendritic cells were most easily transduced probably. *In vitro* transduction of the cells prevents the lentiviral vectors to integrate their genome into a variety of host cells in a hazardous manner. For this reason, *in vitro* transduced cells should constitute an appropriate and safe delivery method for a first clinical application.

[0092] Warner et al were first showing the capacity of retroviral vector to induce efficient CTL responses in several animal models but also in HIV patients using murine retroviral vector-transduced fibroblast expressing HIV-1 proteins (reviewed by Warner 1998). Injected directly into the mouse, proviral DNA were detected in dendritic cells which present antigens efficiently (Song, 1997). However, in contrast to the lentiviral vectors, the murine retroviral vectors can not transduce non-dividing cells such as DC and *in vivo* expression of the encoding gene is often subject to « shut off ». Consequently, these retroviral vector are not the best candidate for human immunotherapy (Kafri).

[0093] Our results demonstrate clearly that lentiviral-derived vectors containing the central DNA triplex induce stronger CTL responses *in vivo* in HHD mice than those not containing the central DNA triplex. Furthermore, lentiviral vector containing the central DNA triplex can easily transduce hDC *in vitro* which could be subsequently used for clinical immunotherapy.

## Materials and Methods

### Lentiviral vector constructions

[0094] Vector plasmids: pTRIP-EGFP derived from HR'CMVLacZ (Naldini et al, PNAS 93,11382-8, 1996). LacZ reporter gene was replaced by the EGFP gene (Clontech). In TRIP-EGFP, the EGFP gene was inserted in the ClaI site of a central fragment of HIV-1LAI comprising cPPT and CTS sequences.

EGFP gene was amplified by PCR using Pfu polymerase (Stratagene) from pEGFP-N1 plasmid, adding BamHI and

XhoI restriction sites in 5' and 3' respectively. PCR primers were as following:

**Bam GFP 5' CC GGATCC CCA CCG GTC GCC ACC 3'**

**Xho GFP 5' CC CTCGAG CTA GAG TCG CGG CCG 3'**

HR GFP vector was constructed by cloning back this PCR fragment into BamHI and XhoI sites of pHR'CMVLacZ, replacing the LacZ ORF by EGFP. A 178 bp fragment of pLAI3 (4793 to 4971), encompassing cPPT and CTS, was amplified by PCR. NarI restriction sites were added in 5' of the primers in the aim to insert this fragment into the unique ClaI site of HR GFP:

Nar TRIP+: 5' GTC GTC GGCGCC GAATTC ACA AAT GGC AGT ATT CAT CC 3'

Nar TRIP-: 5' GTC GTC GGCGCC CCA AAG TGG ATC TCT GCT GTC C 3' Insertion of this triplex sequence in the correct orientation gave rise to the TRIP GFP plasmid vector, and TRIPinv GFP in the reverse orientation. Alternatively, the same triplex fragment was amplified from pcPPT-AG, pcPPT-D, pcPPT-225 and pCTS plasmids to generate vectors including the same mutations in the cPPT or in the CTS as the corresponding viruses.

**[0095]** First, the EcoRI site present in the TRIP GFP vector or TRIP-EGFP (deposited at the CNM under n° I-2005 on April 15, 1998) was filled, creating the TRIP GFP ΔE vector. Then a 1.2Kb BamHI/XhoI fragment containing the internal ribosome entry site (IRES) of a picornavirus was cloned up-stream the EGFP instead of the 0.7kb BamHI/XhoI EGFP in a TRIP GFP ΔE vector, creating the TRIP ΔE IRES GFP vector. The sites present between the CMV promoter and the IRES GFP sequence are BamHI-BstXI-SnaBI and EcoRI. A CTL polypeptide melanoma (mel) fragment was generated by PCR on the pBS mel poly, inserting a kozac consensus sequence inside the primers 5BglMlu Mel:

**5'CCAGATCTACGCGTGCCACCATGGCTGCTGGT 3'**

**3RIMel: 5'CGGAATTCGACCTAAACGCAACGGATG3'.**

**[0096]** The mel PCR fragment was digested by BglII/EcoRI and inserted in the BamHI/EcoRI sites of TRIP ΔE IRES GFP, creating the TRIP ΔE mel IRES GFP also called TRIP mel IRES GFP.

**[0097]** The HR mel IRES GFP was created by exchanging the NdeI/XhoI fragment containing the melanoma polypeptide and the IRES GFP of TRIP mel IRES GFP with that of HR GFP. The NdeI site is situated at the end of the CMV promoter.

#### **Production of viral vectors.**

**[0098]** The lentiviral vectors were produced as described previously (Naldini I.M. PNAS 1996 and science 1996) by a transient tree-plasmid transfection of 293T cells using the phosphate-calcium technique. Briefly, 293T cells were transfected with 20μg of the VSV envelope plasmid (pMDG) and 40μg of the various packaging (8.2 or 8.91) and lentiviral vector plasmids. Conditioned media were collected 60h and 84h after transfection. The virus was then concentrated and dNTPs were treated as previously described (Naldini science 1996). Viral titres on HeLa P4.2 cells and MT4 cells were determined by serial dilution and p24 ELISA assay (Naldini Science 1996).

**[0099]** One cycle titration of viruses were performed in triplicate by infection of P4 cells plated in 96 well plates, with equivalent amounts of particules (1ng of p24 viral antigen per well), in the presence of 20 μM of DEAE-dextran. The protease inhibitor Saquinavir (Roche), was added at 1μM throughout the experiment, to restrict the analysis to a single cycle of infection. Cell mitosis was inhibited by aphicolin treatment (8 μM), the day prior infection. The β-galactosidase activity was measured 48 h after infection using a chemiluminescent β-Gal reporter gene assay (Boehringer).

**[0100]** HeLa cells were infected in triplicate with equivalent amount of vector particules (5 ng P24 per well). At 48 hours post transduction, medium was replaced by 200 μl of TNB (Tris 50 mM pH 7.5, NaCl 150 mM) and fluorescence of living cells quantitated using a microplate fluorimeter (Victor<sup>2</sup>, Wallac) and EGFP adapted filters (excitation: 485 nm, emission: 520 nm).

**[0101] Mice.** HHD mice have been described previously (Pascolo, 1997). They express a transgenic monochain histocompatibility class I molecule in which the C terminus of the human b2m is covalently linked by a peptidic arm (GGGGS) x 3 to the N terminus of a chimerical heavy chain (HLA-A2.1 a1-a2, H-2D<sup>b</sup> a3 - transmembrane, and intra-cytoplasmic domains). The H-2D<sup>b</sup> and mouse b2m genes of these mice have been further disrupted by homologous recombination resulting in complete lack of serologically detectable cell surface expression of mouse histocompatibility

class I molecules.

#### Generation of hDC and primary CTL induction.

[0102] Human dendritic cells were obtained from cytopheresis products of healthy donors of HLA-A2.1 haplotype (IDM. Paris, France). FACS analysis of these DC using mAbs against CD3, CD14, CD80, CD83, HLA-ABC, and HLA-DR showed immature DC phenotype. The hDC were transduced in 1 ml AMV-5 culture medium with the lentiviral vectors at concentrations of 600ng, 300ng, 150ng, and 150ng/p24 per  $1.10^6$  cells for ten days. The percentage and mean fluorescence intensity of GFP expression in hDC transduced with the two lentiviral vectors were measured by FACS (Becton Dickinson, BD, USA).

[0103] Mononuclear cells (MNC) from the same donor were stimulated *in vitro* by the hDC or transduced hDC with a ratio of 4 MNC to 1 hDC. The MNC were restimulated twice using the same cryopreserved-transduced hDC and then tested for cytolytic activity in a 4 h  $^{51}\text{Cr}$ -release assay, using as targets T2 cells loaded with relevant or negative control (Inf.m.58) peptides (10 pg/ml,  $5.10^6$  cells/ml, in FCS-free RPMI medium, 2 h at RT).

#### Generation of murine dendritic cells

[0104] Bone marrow-derived dendritic cells were generated as previously described [43, 51]. Bone marrow mononuclear cells were cultured in RPMI supplemented with 10% FCS, 2 mM L glutamine, 50 U/ml penicillin, 50 µg/ml streptomycin,  $5.10^5$  M 2- mercaptoethanol (complete RPMI medium), further supplemented with 20 ng/ml recombinant mouse GM-CSF and 100 ng/ml recombinant mouse IL4 (both from GENZYME, Cambridge, MA). On day 2 and 6, non adherent cells were carefully removed, and fresh complete RPMI medium, supplemented with 10 ng/ml mouse GM-CSF and 50 ng mouse IL4, was added. On day 7, the culture medium was replaced by 1ml complete RPMI medium supplemented with the lentiviral vectors at concentrations of 600ng, 300ng, 150ng, and 150ng/p24 per  $1.10^6$  cells. Dendritic cells collected on day 9 were more than 95% pure (IA $^b$ +, HHD+, CD3-, 33D1+, NDL145+, and CD 11c+), as assessed with appropriate mAb. Percentage and mean intensity of fluorescence of GFP expression in murine DC was then measured at day 9 and 12 by FACS.

#### Vector immunization and *In vitro* restimulation and cytolytic assays

[0105] HHD mice were injected either intraperitoneally, intravenously or subcutaneously with lentiviral vectors for 12 days. Spleen cells from primed mice were then individually restimulated in complete RPMI medium by each epitopic peptide for seven days. The last two days, the cultured cells were restimulated by 10% TCGF. On day 7, cultured cells were tested for cytolytic activity as already described (Pascolo, 1997), in a 4 h  $^{51}\text{Cr}$ -release assay, using as targets HHD-transfected TAP- RMA-S cells loaded with relevant or negative control (Inf.m.58) peptides (10 µg/ml,  $5.10^6$  cells/ml, in FCS-free RPMI medium, 2 h at RT). The TRIP-mel-ITES- GFP transduced or non transduced HHD-transfected HeLa cells were parallelly used as target cells. The percentage of specific lysis was calculated as follows: (experimental release - spontaneous release)/(total release - spontaneous release) x 100.

#### Example II: Evaluation of CTL responses in HHD mice after immunization with the TRIP-des-IRES-GFP vector encoding the DES gene of *Mycobacterium tuberculosis*.

[0106] The DES gene is disclosed in WO 98/04711.

#### Experimental procedure

[0107] In a first step, the TRIP-des-IRES-GFP vectors were used to transduce HeLa-HDD cells. These cells were transduced and cloned by limiting dilution. The clone expressing the higher level of GFP was selected to use as target cells in classical  $^{51}\text{Cr}$ CTL tests.

[0108] In a second step, HDD mice were injected intraperitoneously using 1.2 micg/p24 per mouse of the TRIP-des-IRES-GFP vector particles. Spleen cells of these mice were *in vitro* stimulated at 12 days post-injection with either 0.2 micg, or 1 micg/p24/ml ( $2.10^6$  cells per ml) of vector particles or with TRIP-des-IRES-GFP transduced, LPS stimulated syngeneic blast cells with 1 micg/p24/ml/ $2.10^6$  cells/ml. Six days after *in vitro* stimulation, cytolytic capacity of cells was tested in a  $^{51}\text{Cr}$  test using *des* transduced HeLa-HDD target cells. Control target cells were HeLa-HDD cells transduced by the melanoma polyepitope (TRIP-mel-IRES-GFP).

## Results

[0109] These experiments have been performed to study if HIV derived triplex positive vectors encoding a whole gene is capable of transducing cells and of inducing specific CTL responses against the target cells expressing the same gene. As illustrated in figure 9, specific lysis is obtained in all conditions. Transduced LPS- blast cells induced weak CTL responses. The best results were obtained using 1 micg/p24/ml of vector particles. These results show that an entire gene can be introduced in the genome of the host cell and its product is processed, presented and induce significant CTL responses. These results demonstrate also that des gene contains at least one or more HLA-A2.1 restricted CTL epitopic peptides.

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[0110]

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Annex to the application documents - subsequently filed sequences listing

[0111]

5

SEQUENCE LISTING

10

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CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

15

<120> VECTORS FOR THE PREPARATION OF IMMUNOTHERAPEUTICAL  
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## Claims

1. Immunogenic composition comprising a recombinant vector characterized in that it comprises a polynucleotide comprising the cis-acting central initiation region (cPPT) and the cis-acting termination region (CTS), these regions being of retroviral or retroviral-like origin, said vector comprising in addition a defined nucleotide sequence (transgene or sequence of interest) and regulatory signals of retrotranscription, expression and encapsidation of retroviral or retroviral-like origin, wherein the composition is capable of inducing or of stimulating a cell-mediated response for instance a CTL (Cytotoxic T Lymphocytes) response or a CD4 response, against one or several epitopes encoded by the transgene sequence present in the vector.
2. Immunogenic composition according to claim 1, wherein the generated CTL response is a memory CTL response.
3. Immunogenic composition according to claim 1, characterized in that the sequences of retroviral origin are derived from a lentivirus genome.
4. Immunogenic composition according to anyone of Claims 1 to 3, characterized in that the transgene or the sequence of interest is contained in an expression cassette including regulatory signals of transcription and expression.
5. Immunogenic composition comprising recombinant retroviral particles comprising 1) a recombinant nucleotide sequence containing a defined nucleotide sequence (transgene), placed under the control of regulatory signals of transcription and expression, regulatory signals of retrotranscription, expression and encapsidation and 2) a polynucleotide comprising the cis-acting central initiation region (cPPT) and the cis-acting termination region (CTS), these regions being of retroviral or retroviral-like origin or from a transposon and being inserted in a functional orientation and location with retrotranscription regulatory signals of retroviral or retroviral-like origin or transposons regulatory signals, wherein the immunogenic composition is capable of inducing or of stimulating a cell-mediated response, such as a CTL (Cytotoxic T Lymphocytes) response or a CD4 response against one or several epitopes encoded by the transgene sequence present in the vector.
6. Immunogenic composition comprising recombinant retroviral vector particles comprising :
  - a) a gag polypeptide corresponding to nucleoproteins of a lentivirus or to functional derived polypeptides (GAG polypeptides),
  - b) a pol polypeptide constituted by the RT, PRO, IN proteins of a lentivirus or a functional derived polypeptide (POL polypeptide),
  - c) an envelope polypeptide or functional derived polypeptides (ENV polypeptides),
  - d) a recombinant nucleotide sequence comprising a defined nucleotide sequence (transgene or a sequence of interest), coding for one or several epitopes, placed under the control of regulatory signals of transcription and expression, a sequence containing regulatory signals of retrotranscription, expression and encapsidation of retroviral or retroviral-like origin and a polynucleotide comprising the cis-acting central initiation region (cPPT) and the cis-acting termination region (CTS), these regions being of retroviral or retroviral-like origin and being inserted in a functional orientation and location with the above-mentioned regulatory signals of retroviral or retroviral-like origin, wherein the composition is capable of inducing or of stimulating a CTL (Cytotoxic T Lymphocytes) response against one or several epitopes encoded by the transgene sequence present in the vector.
7. Immunogenic composition wherein the recombinant retroviral-like particles comprise:
  - a) a polynucleotide comprising the cis-acting central initiation region (cPPT) and the cis-acting termination region (CTS), these regions being derived from a retrotransposon and inserted in a functional orientation with retrotransposon regulatory signals,
  - b) a polypeptide corresponding to the nucleoproteins of a retrotransposon or to functional derived polypeptides (GAG polypeptides)
  - c) a pol polypeptide corresponding to RT, PRO, IN proteins of a retrotransposon or a functional derived polypeptide (POL polypeptide),
  - d) a viral envelope polypeptide,
  - e) a recombinant nucleotide sequence comprising a defined nucleotide sequence (transgene or sequence of interest), placed under the control of regulatory signals of transcription and expression, retrotransposon reg-

ulatory signals of retrotranscription, expression and encapsidation, wherein the composition is capable to induce or to stimulate a cell-mediated for instance a CTL (Cytotoxic T Lymphocytes) response or a CD4 response against one or several epitopes encoded by the transgene sequence present in the vector, wherein the composition is capable of inducing or of stimulating a cell-mediated response CTL (Cytotoxic T Lymphocytes) response or a CD4 response, against one or several epitopes encoded by the transgene sequence.

8. Immunogenic composition according to anyone of Claims 5 to 7, wherein the generated CTL response is a memory CTL response or CD4 response.
9. Immunogenic composition according to anyone of Claims 1 to 8, characterized in that the regulatory signals of retrotranscription, expression and encapsidation are of lentiviral origin, and the polynucleotide comprising the cPPT and CTS regions is of lentiviral origin.
10. Immunogenic composition according to anyone of Claims 1 to 9, characterized in that the regulatory signals of retrotranscription, expression and encapsidation and the polynucleotide comprising the cPPT and CTS regions in the vector, are derived from a HIV-type retrovirus, in particular HIV-1 or HIV-2.
11. Immunogenic composition according to Claim 10, characterized in that the regulatory signals of retrotranscription, expression and encapsidation and the polynucleotide comprising the cPPT and CTS regions, are derived from a virus selected from the lentiviruses CAEV, EIAV, VISNA, HIV, SIV or FIV.
12. Immunogenic composition according to anyone of the Claims 1 to 11, characterized in that the polynucleotide of the vector is a DNA sequence comprising the cis-acting central initiation region (cPPT) and the termination region (CTS) of a HIV-1 retroviral genome.
13. Immunogenic composition according to anyone of Claims 5 to 12, characterized in that the gag, pol and env sequences of the vector particles are derived from the sequences of a HIV retrovirus, in particular HIV-1 or HIV-2.
14. Immunogenic composition according to anyone of Claims 5 to 12, characterized in that the gag and pol sequences are derived from the sequences of a HIV retrovirus and the env sequence is derived from a different HIV retrovirus or from a virus.
15. Immunogenic composition according to Claim 14, characterized in that the env sequence codes for amphotropic ENV polypeptides.
16. Immunogenic composition according to Claim 14, characterized in that the env sequence codes for ecotropic ENV polypeptides.
17. Immunogenic composition according to Claim 14, characterized in that the env sequence is derived from the vesicular stomatitis virus (VSV).
18. Vector characterized in that it is the plasmid pTRIP.TEUAML-IRES-EGFP, deposited with the CNCM on October 11, 1999, under number I-2326, or a Ptrip.DES-IRES-GFP deposited with the CNCM on October 11, 1999, under I- 2331.
19. Vector characterized in that it is the plasmid pTRIP.ILKE-IRES-GFP, deposited with the CNCM on October 11, 1999, under number I- 2327.
20. Recombinant cell which has been contacted with an immunogenic composition according to anyone of Claims 1 to 17.
21. Recombinant cell according to claim 20, which is an Antigen Presentating Cell or a cell chosen among lung cells, brain cells, epithelial cells, astrocytes, microglia, oligodendrocytes, neurons, muscle, hepatic, dendritic, neuronal cells, cells strains of the bone marrow, macrophages, fibroblasts, hematopoietic cells.
22. Immunogenic composition or recombinant cell according to anyone of Claims 1 to 17, for the therapeutic treatment of tumors or infectious diseases.

23. Immunogenic composition according to anyone of Claims 1 to 17, wherein the transgene included in the vector is an epitope, a polypeptide comprising a polypeptide, a protein derived from a tumor cell or from an infectious agent.
24. Immunogenic composition according to claim 23, wherein the epitope, polypeptide comprising a polypeptide or the protein is derived from melanoma cells.
25. Composition according to anyone of Claims 1 to 17 or vector or vector particle defined in any of Claims 1 to 17, wherein the cPPT and CTS regions have a central localization within the sequence of the vector.
26. Composition according to anyone of Claims 1 to 17 or vector or vector particle defined in any of Claims 1 to 17, wherein the transgene is inserted in the U3 region of the regulation signals for retrotranscription.
27. Recombinant vector characterized in that it comprises a polynucleotide containing a cis-acting central initiation region (cPPT) and a cis-acting termination region (CTS), these regions being of retroviral or retroviral-like origin, said vector comprising in addition a defined nucleotide sequence (transgene or sequence of interest) which nucleotide sequence is the sequence of a gene of a pathogenic agent, and regulatory signals of retrotranscription, expression and encapsidation of retroviral or retroviral-like origin, wherein the composition is capable of inducing or of stimulating a cell-mediated response for instance a CTL (Cytotoxic T Lymphocytes) response or a CD4 response, against one or several epitopes encoded by the transgene sequence present in the vector.
28. Recombinant vector according to claim 27, wherein the nucleotide sequence of interest or transgene, is a gene encoding an antigen of a bacteria, for instance a mycobacteria, especially *Mycobacterium tuberculosis*.
29. Recombinant vector according to claim 27, wherein the nucleotide sequence of interest or transgene, is a gene encoding an antigen of a virus or retrovirus.
30. Vector according to claim 18 or 19, wherein the TEL/AML or the ILKE epitopes are replaced by all or part of a gene of a pathogenic agent, for instance by the DES gene of *M tuberculosis*.
31. Immunogenic composition according to anyone of claims 1 to 17 which is capable of inducing or stimulating the nuclear import of the genome of the vector in target cells.
32. Use of a vector according to anyone of claims 18 or 19 or 27 to 31 in an immunogenic composition according to anyone of claims 1 to 17.
33. Use of a nucleotidic sequence comprising the cPPT and CTS regions which adopt a three-stranded DNA structure (the DNA triplex) after reverse transcription in a lentiviral or retrotransposon vector and stimulates the rate of entry of the vector DNA into the nucleus of the transduced cell.
34. Use of the nucleotidic sequence according to claim 33 for the induction of a cellular response in a cell or in a patient.
35. A three-stranded DNA sequence induced by the cPPT and CTS regions capable of inducing a high rate of entry or increasing the rate of nuclear import of the vector DNA.

Figure 1 : HIV1-derived central DNA positive recombinant vector encoding a melanoma polypeptide

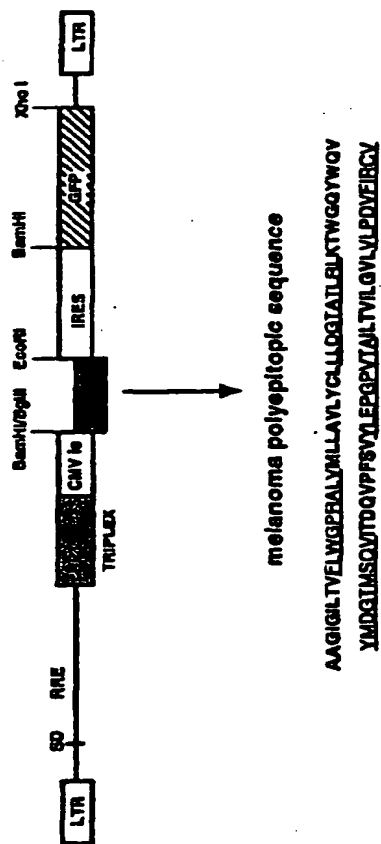
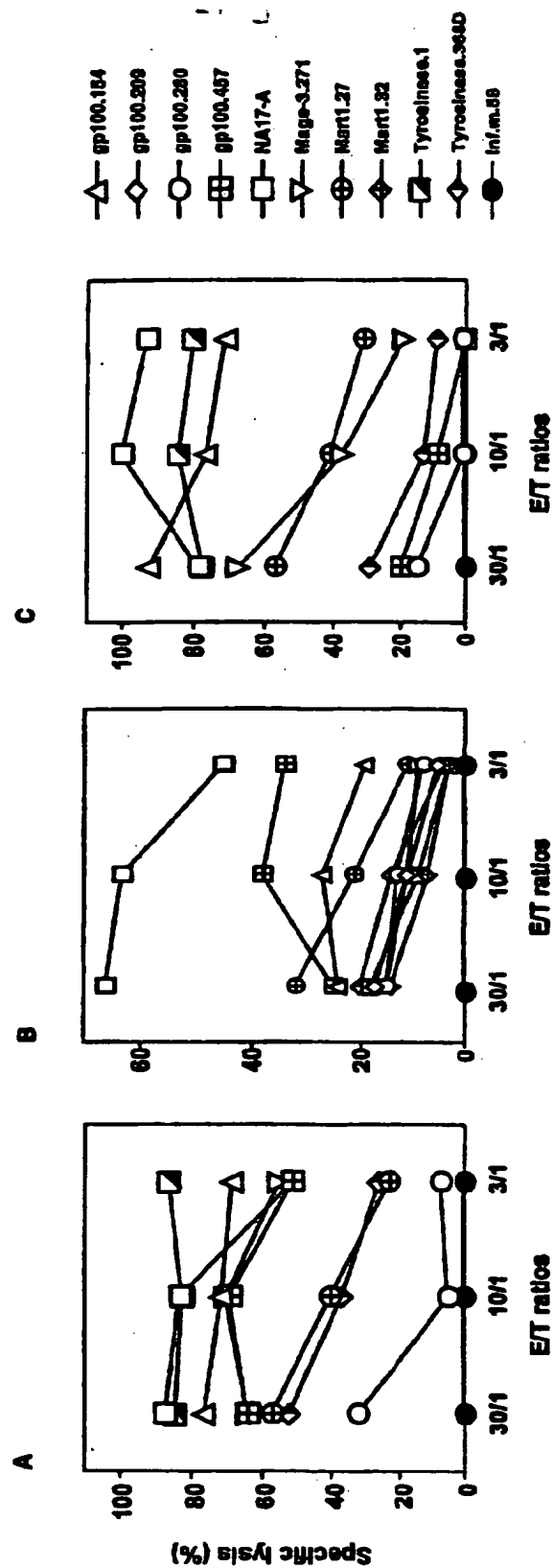
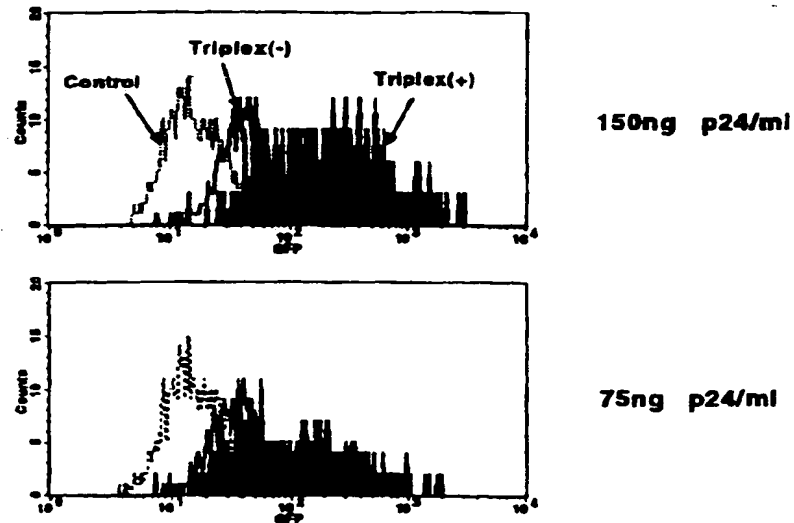


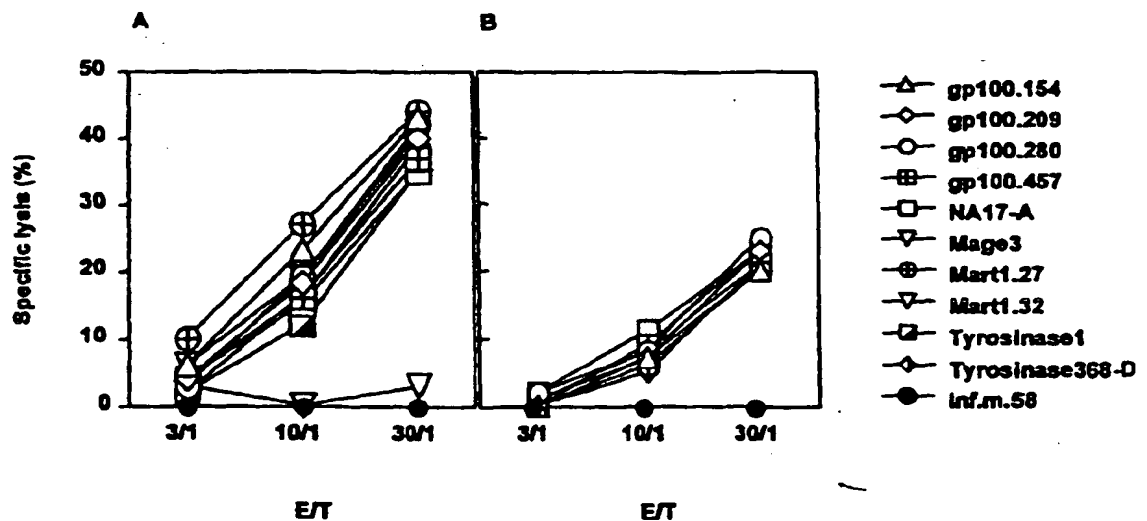
Figure 2: CTL responses of HHD mice after immunization with the TRIP-mel-IRES-GFP vector



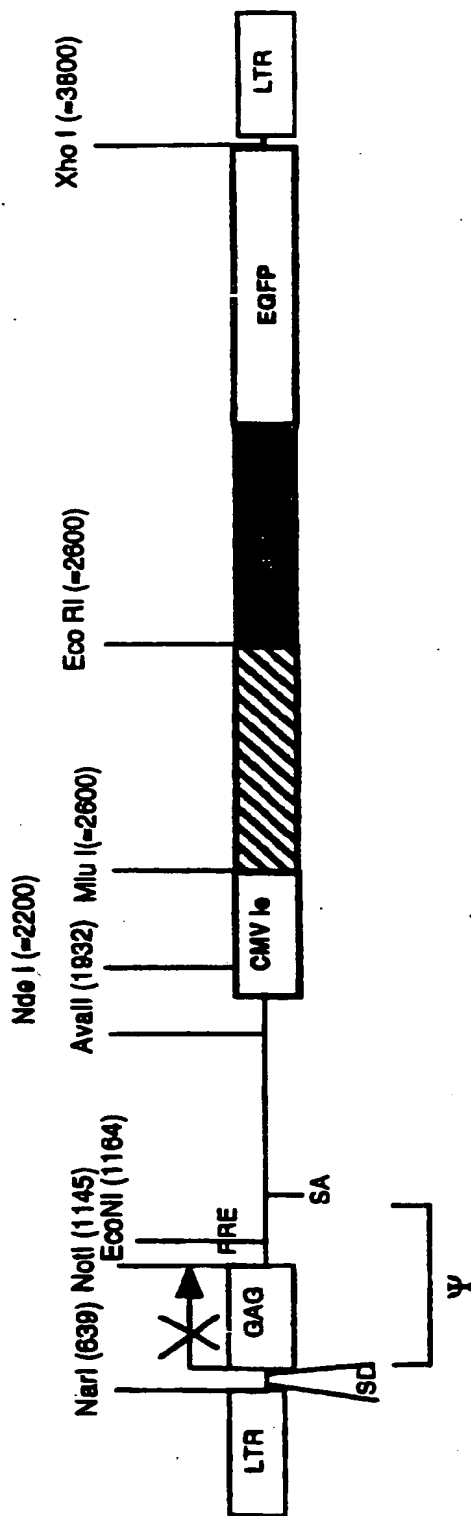
**Figure 3 : GFP expression in human dendritic cells 5 days after their transduction by the central DNA triplex positive or negative HIV 1-derived vectors**



**Figure 4 : In vitro CTL responses using human dendritic cells**



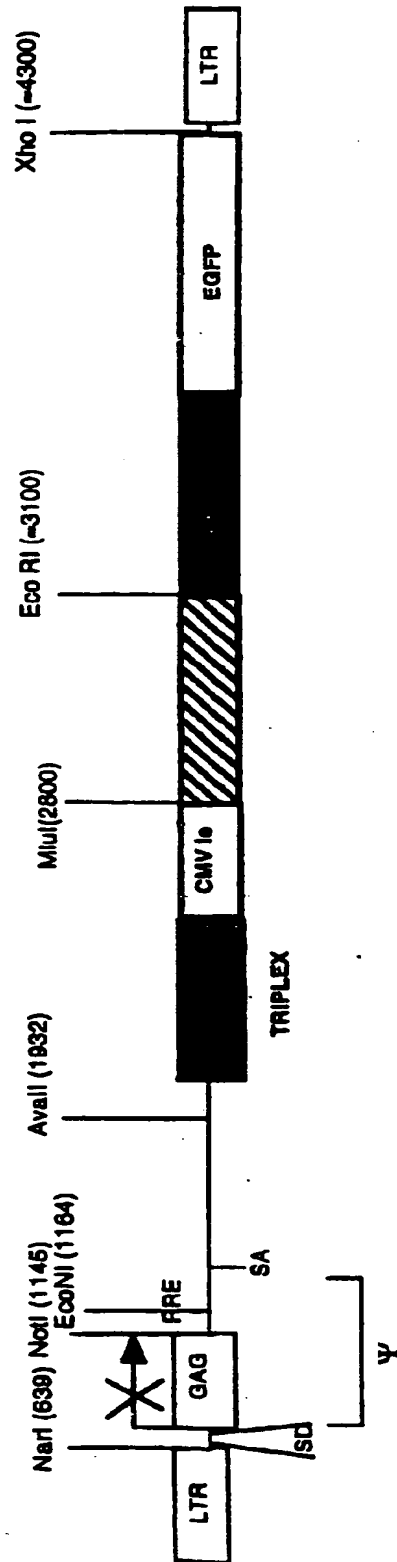
# CARTE DE RESTRICTION DU VECTEUR pHR.MEL-RES-GFP



 : Séquences mono ou polypeptiques CTLs spécifiques du Mélanome.

FIGURE 5

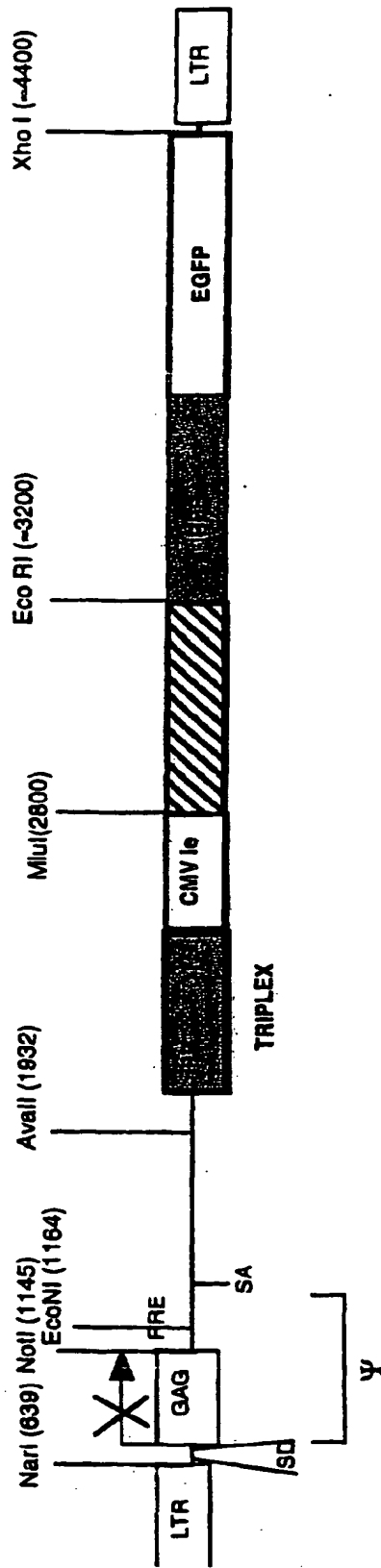
CARTE DE RESTRICTION DU VECTEUR pTRIP.ILKE-IRES-GFP



▨ : Séquences mono ou polyépitopiques CTLs spécifique du HIV dont l'épitope ILKE (RT 476 - 484)

FIGURE 6

**CARTE DE RESTRICTION DU VECTEUR pTRIP.TEL/AML-IRES-GFP**



 : Séquence la translocation TEL/AML.

FIGURE 7

Transduction capacity of HIV-derived DNA triplex positive vector encoding I9V epitopic peptide (derived from HIV 1 pol) and GFP of murine dendritic cells that were produced using bone marrow cells from HHD transgenic mice.

About 80% of murine dendritic cells are transduced by the HIV derived triplex positive recombinant vector as documented by FACS analyses of intra cellular GFP expression.



FIGURE 8

Figure 2 : Evaluation of CTL responses in HHD mice after immunization with the TRIP-des-IRES-GFP vector encoding the DES gene of Mycobacterium tuberculosis

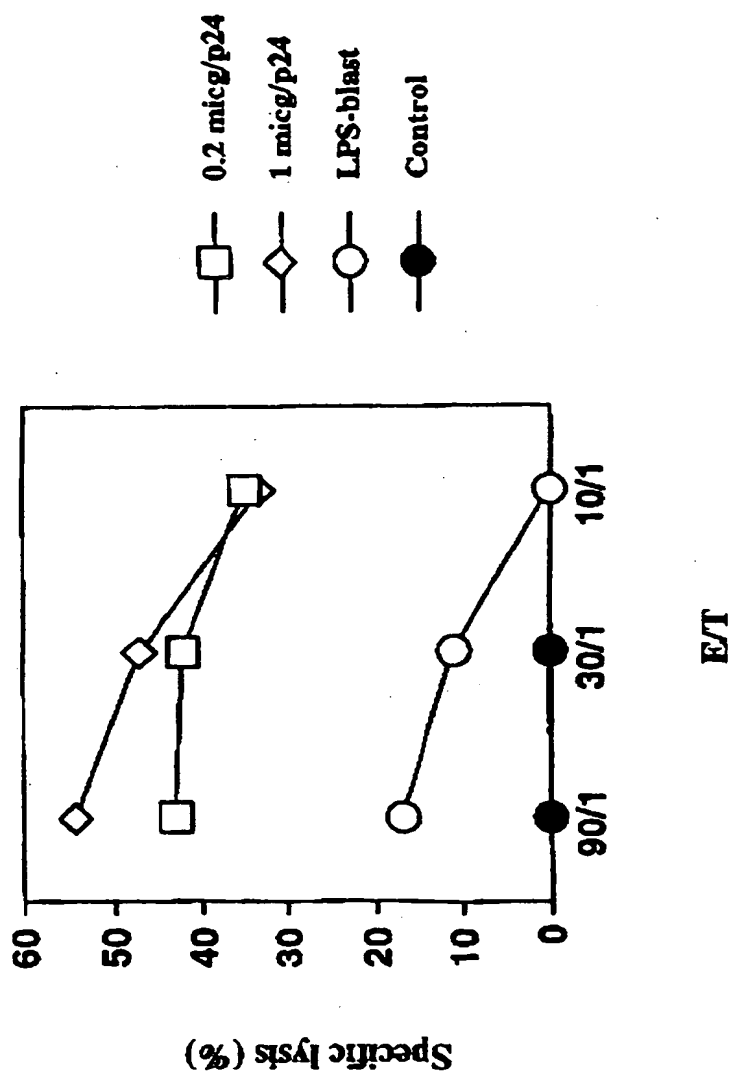
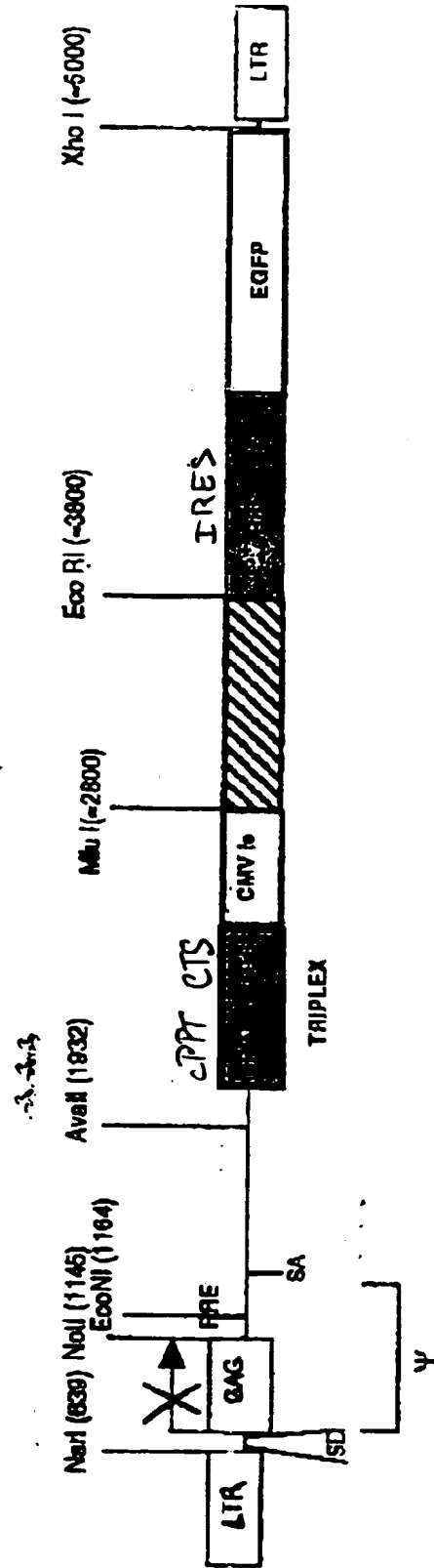


FIGURE 9

# CARTE DE RESTRICTION DU VECTEUR pTRIP.DES-IRF5-GFP



 : gene DES de mycobacterium tuberculosis.

FIGURE 10



European Patent  
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# PARTIAL EUROPEAN SEARCH REPORT

which under Rule 45 of the European Patent Convention shall be considered, for the purposes of subsequent proceedings, as the European search report

Application Number

EP 99 40 2492

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
F.L.	WO 99 55892 A (CHARNEAU PIERRE :FIRAT HUESEYIN (FR); PASTEUR INSTITUT (FR); ZENNO) 4 November 1999 (1999-11-04)  * L: Priority * * the whole document *	1-17, 20-25, 27-29, 31-34	C12N15/86 C12N7/01 C12N5/10 C07K14/35 A61K48/00
X	WO 98 39463 A (UEBERLA KLAUS) 11 September 1998 (1998-09-11)	1-6, 8-17, 20-23, 25, 27-29, 31-34	
Y	* the whole document *	35	
Y	RIZVI T. A. ET AL.: "Propagation of HIV vectors by genetic complementation with a heterologous env gene." AIDS RESEARCH AND HUMAN RETROVIRUSES, vol. 8, no. 1, 1992, pages 89-95, XP002078382 * the whole document *	1-6,8,9, 11, 20-23, 25, 27-29, 31-34	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			C12N C07K A61K
<p><b>INCOMPLETE SEARCH</b></p> <p>The Search Division considers that the present application, or one or more of its claims, does/do not comply with the EPC to such an extent that a meaningful search into the state of the art cannot be carried out, or can only be carried out partially, for these claims.</p> <p>Claims searched completely:</p> <p>Claims searched incompletely:</p> <p>Claims not searched:</p> <p>Reason for the limitation of the search:</p> <p>see sheet C</p>			
Place of search:		Date of completion of the search	Examiner
THE HAGUE		10 March 2000	Mandl, B
<p><b>CATEGORY OF CITED DOCUMENTS</b></p> <p>X: particularly relevant if taken alone Y: particularly relevant if combined with another document of the same category A: technological background O: non-written disclosure P: intermediate document</p> <p>T: theory or principle underlying the invention E: earlier patent document, but published on, or after the filing date D: document cited in the application L: document cited for other reasons</p> <p>&amp; member of the same patent family, corresponding document</p>			

EP 1 092 779 A1 (1999-11-04)



European Patent  
Office

**INCOMPLETE SEARCH  
SHEET C**

Application Number

EP 99 40 2492

Although claims 33 and 34, as far as an in vivo application is concerned, are directed to a method of treatment of the human/animal body (Article 52(4) EPC), the search has been carried out and based on the alleged effects of the compound/composition.



European Patent  
Office

## PARTIAL EUROPEAN SEARCH REPORT

Application Number  
EP 99 40 2492

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (InCL.7)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
Y,D	CHARNEAU ET AL.: "HIV-1 Reverse transcription" JOURNAL OF MOLECULAR BIOLOGY, GB, LONDON, vol. 241, no. 5, 2 September 1994 (1994-09-02), pages 651-662, XP002090794 ISSN: 0022-2836	35	
A	* the whole document *	1-34	
A,D	CHARNEAU ET AL.: "A second origin of DNA plus-strand synthesis is required for optimal Human Immunodeficiency Virus replication" JOURNAL OF VIROLOGY, US, NEW YORK, US, vol. 66, no. 5, 1 May 1992 (1992-05-01), pages 2814-2820, XP002090796 ISSN: 0022-538X	1-35	
	* the whole document *		TECHNICAL FIELDS SEARCHED (InCL.7)
A	STETOR S. R. ET AL.: "Characterization of (+) strand initiation and termination sequences located at the center of the equine infectious anemia virus genome." BIOCHEMISTRY, vol. 38, 1999, pages 3656-3667, XP002132809	1-35	
	* the whole document *		
A	SÄLLBERG M. ET AL.: "Characterization of humoral and CD4+ cellular responses after genetic immunization with retroviral vectors expressing different forms of hepatitis B virus core and e antigens." JOURNAL OF VIROLOGY, vol. 71, no. 7, July 1997 (1997-07), pages 5295-5303, XP002132810	1-35	
	* the whole document *		

EPO FORM 1503 03.82 (PAC10)

ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.

EP 99 40 2492

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on. The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

10-03-2000

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9955892 A	04-11-1999	FR 2777909 A	29-10-1999
WO 9839463 A	11-09-1998	AU 7332198 A	22-09-1998

EPO FORM P059

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82



**Figure 1: MSV-derived central DNA positive recombinant vector encoding a melanoma polyprotein**

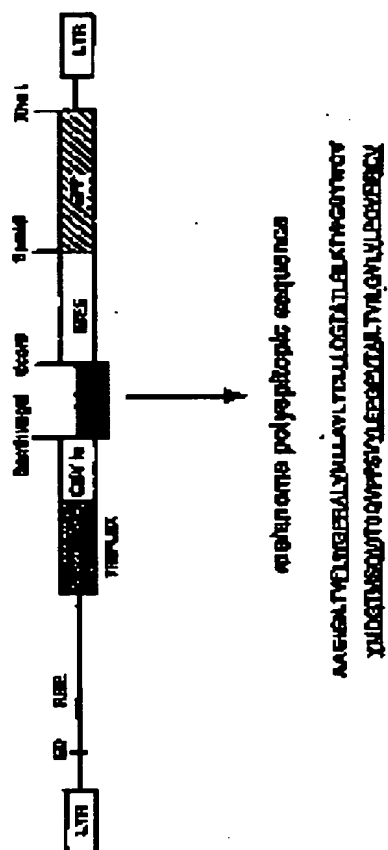
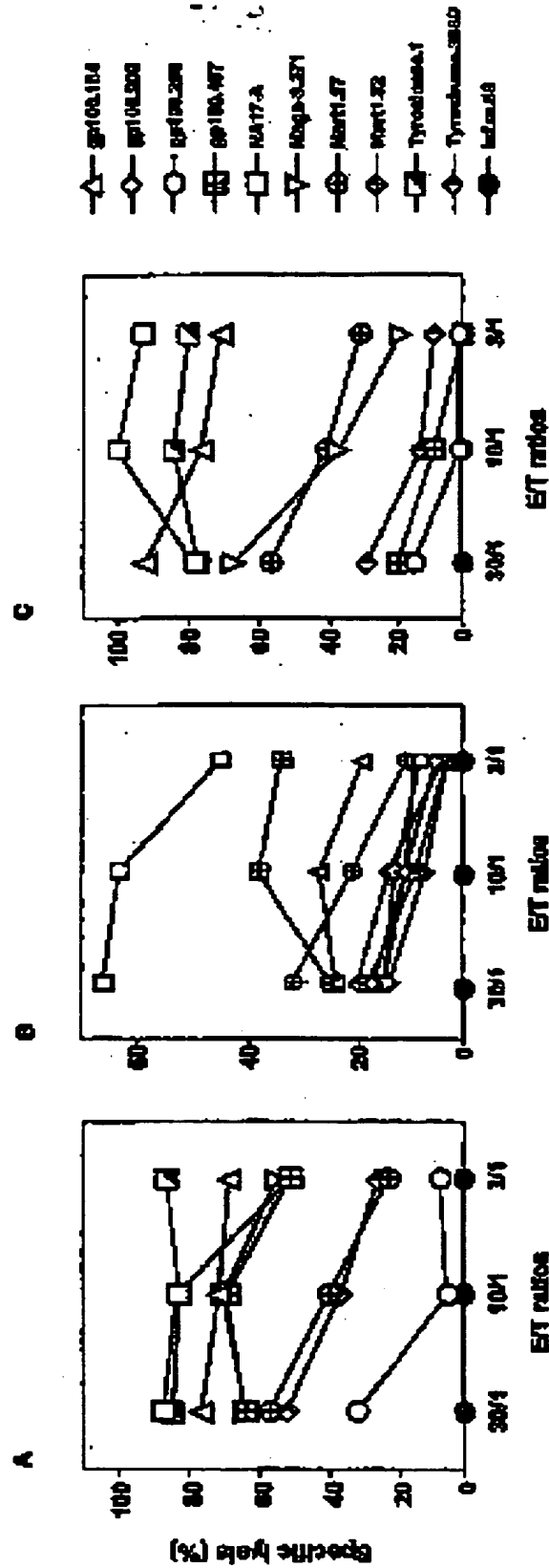
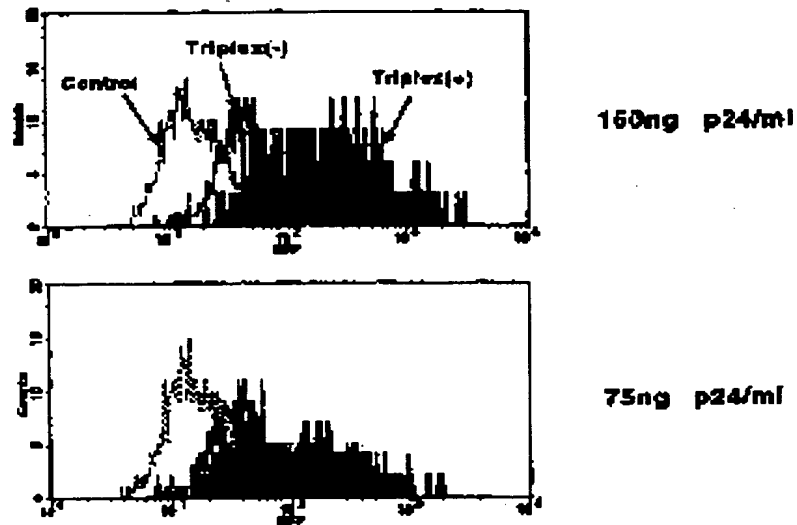


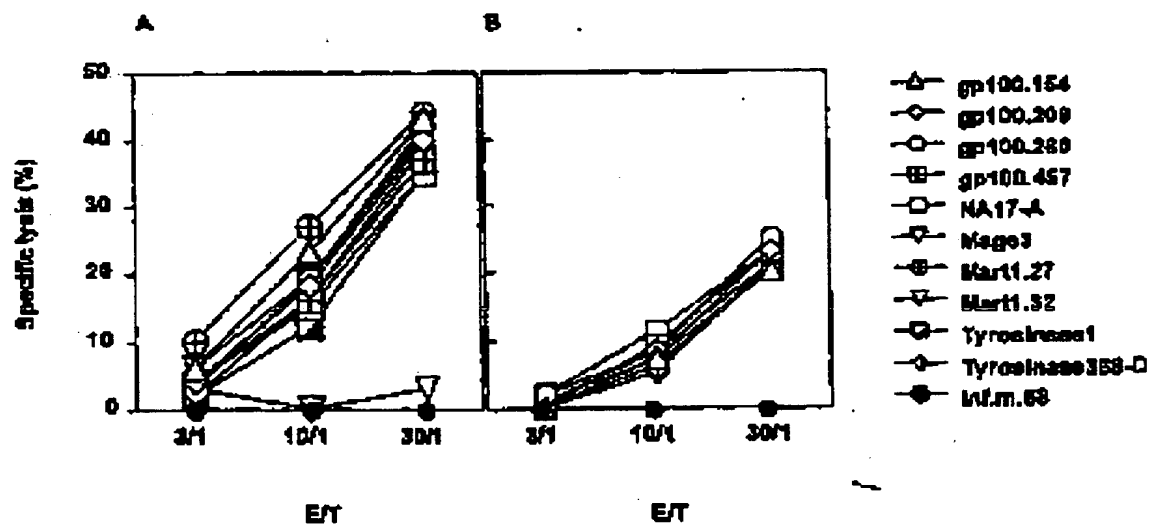
Figure 2: CTL responses of HHD mice after immunization with the TRIP-mel-ERES-GFP vector



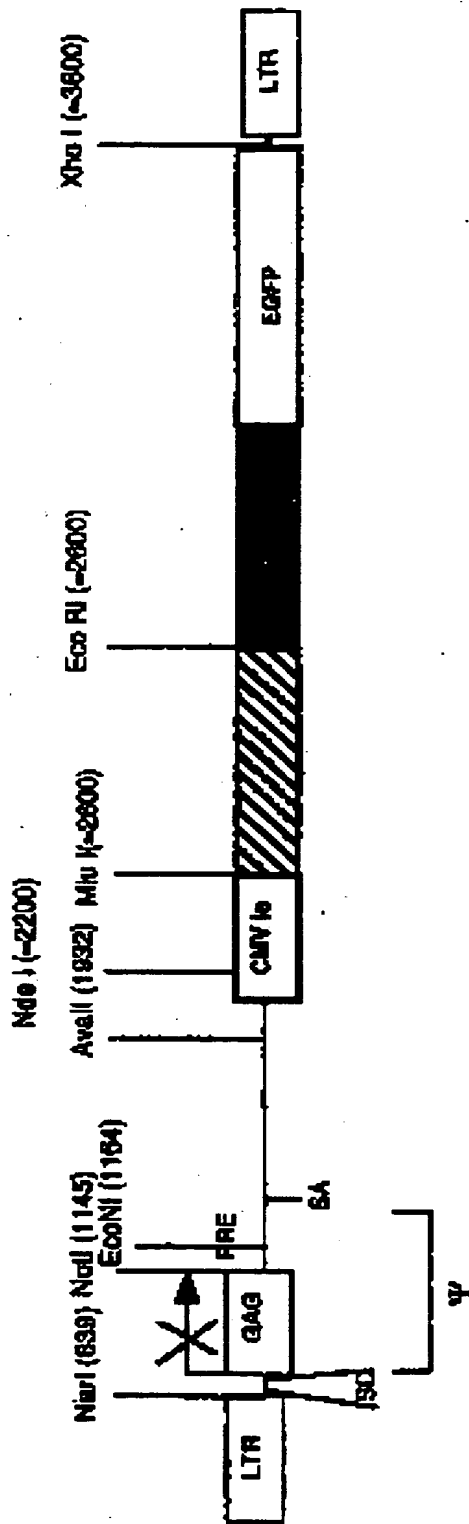
**Figure 3 : GFP expression in human dendritic cells 6 days after their transduction by the central DNA triplex positive or negative HIV 1-derived vectors**



**Figure 4 : In vitro CTL responses using human dendritic cells**



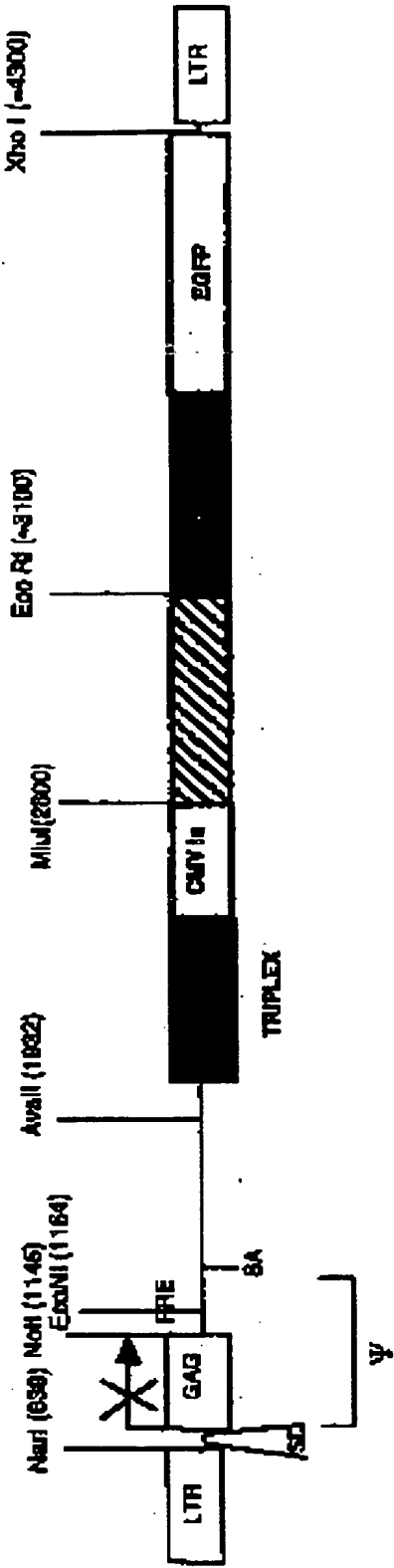
# CARTE DE RESTRICTION DU VECTEUR pHR.MEL-RES-GFP



 : Séquences mono ou polyépitopes CTLs spécifiques du Mélanome.

FIGURE 6

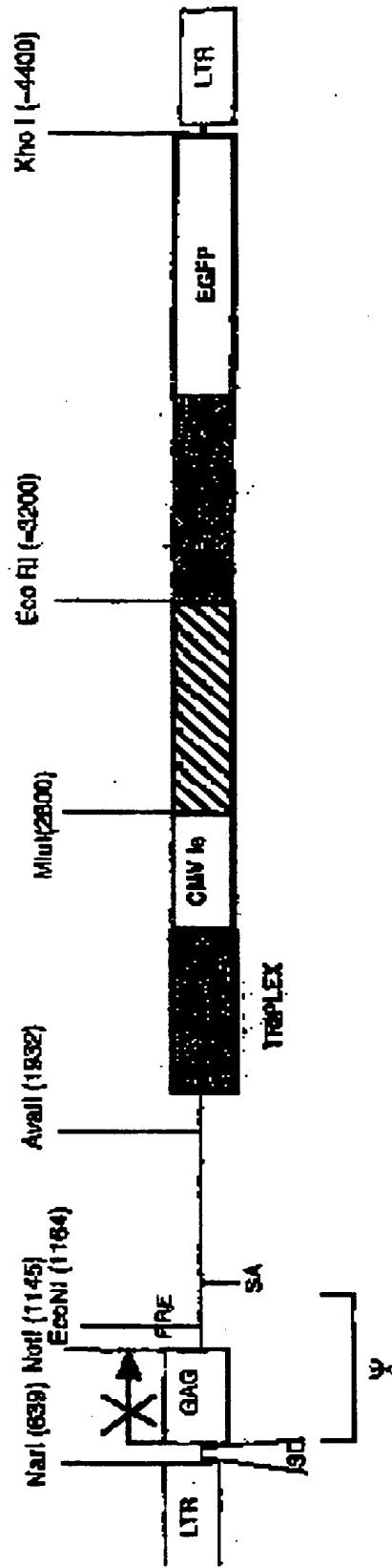
CARTE DE RESTRICTION DU VECTEUR pTRIP.IILKE-IRES-QFP



 : Séquences mono ou polyépitopes CTLs spécifiques du HIV dont l'épitope ILA V (ILKE) (RT 476 - 484)

FIGURE 6

CARTE DE RESTRICTION DU VECTEUR pTRIP.TEL/AML-RIES-QFP



Sequence la translocation TEL/AML.

FIGURE 7

Transduction capacity of HIV-derived DNA triplex positive vector encoding 19V epitopic peptide (derived from HIV 1 pol) and GFP of murine dendritic cells that were produced using bone marrow cells from NED transgenic mice.

About 80% of murine dendritic cells are transduced by the HIV derived triplex positive recombinant vector as documented by FACS analysis of intra cellular GFP expression.

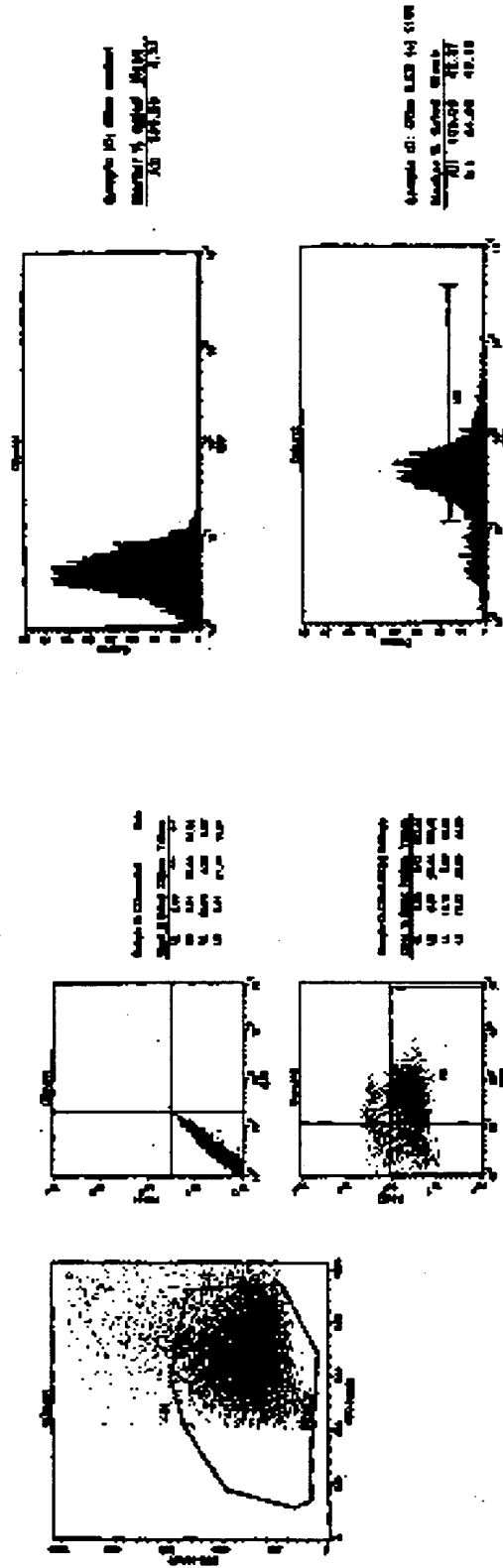
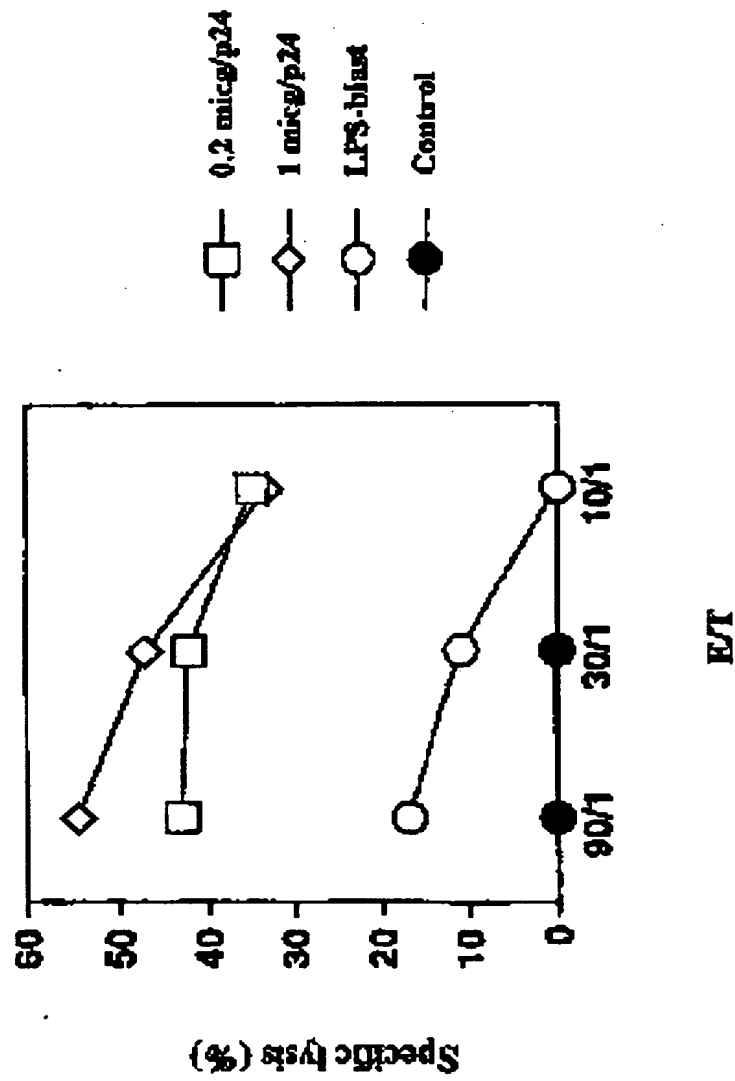


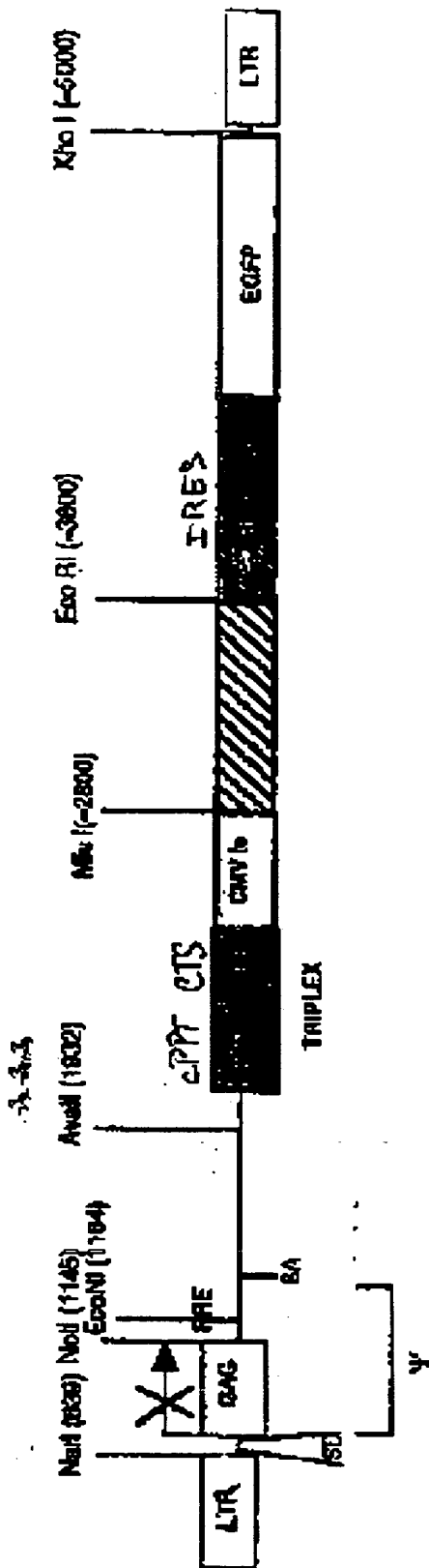
FIGURE 8

**Figure 2 : Evaluation of CTL responses in HFD mice after immunization with the TRIP-des-IRES-GFP vector encoding the DES gene of *Mycobacterium tuberculosis***



**FIGURE 9**

**CARTE DE RESTRICTION DU VECTEUR pTRIP.OES-IR $\Phi$ S-QFP**



**: genes DES de mycobacterium tuberculosis.**

**FIGURE 10**

